EXPERIMENTAL CONSTRAINTS ON THE IRON CONTENT OF THE MARTIAN MANTLE. C. B. Agee and D. S. Draper, Institute of Meteoritics, University of New Mexico, Albuquerque NM 87131, agee@unm.edu.

Summary: High pressure experiments reveal that the CaO/Al_2O_3 of Martian basalt (shergottites) parent magmas can be derived by partial melting at 5 GPa of Homestead L5 chondrite, whose bulk composition is very similar to that of the Dreibus and Wänke [1] model Martian mantle. However, the experimental melts are much richer in FeO than are calculated Martian parent magmas. We conclude that Homestead L5 and the Dreibus and Wänke [1] composition may be too FeO-rich (Mg#, molar Fe/Fe+Mg, ~75) to be considered good candidates for the mantle source region of shergottite parent magmas. This mismatch is well illustrated by comparing the FeO/MnO trends of basaltic shergottites, chondrites, and high pressure partial melts of L-chondrite. From these comparisons we propose that the Martian mantle may be closer in major-element composition to the average value of H-chondrites with Mg#~80. In order to test this hypothesis we are currently carrying out a series of high pressure partial melting experiments on the Farmville H4 chondrite.

Background: Dreibus and Wänke [1] proposed a bulk Mars composition (hereafter "DW-Mars") in which the contents of refractory lithophile elements and iron were based on CI1 chondrite abundances, and the FeO content of the mantle was based on the five shergottite meteorites known at the time. They assumed that Mn was not depleted in the Martian mantle and that the crystal/liquid partition coefficients of MnO and FeO relevant to Martian magmatism were similar and near unity. They also assumed that the FeO/MnO of the shergottite meteorites was a constant value of 39.5±1.2. From these assumptions they calculated an FeO content for the Martian mantle of 17.9±0.6 wt%, with Mg#=75. Ohtani and Kamaya [2] evaluated various Mars models in light of high pressure phase equilbria experiments and likely moment-of inertia values, and called into question the relatively high bulk Fe-content of DW-Mars. They put forward an alternative Mars model with lower bulk Fe and a mantle with Mg#=80. More recently, Bertka and Fei [3] applied Mars Pathfinder moment-of-inertia data and high pressure phase equilibria [4] to conclude that the bulk Fe/Si of DW-Mars was too high. Gilpin et al. [5] carried this work further and argued that mixtures of CI1, L, and H chondrite yield mantle and core compositions that satisfy moment-of inertia, mass, density, and crustal thickness constraints. In the current study we test possible Martian mantle compositions by experimentally determining if they can produce shergottite parent magmas. This approach is independent of geophysical and mineral physics constraints considered by the studies mentioned above, however we reach a similar conclusion that calls for a Martian mantle with a lower FeO-content and higher Mg# than DW-Mars.

Iron/Manganese: Figure 1 illustrates that there is a distinct FeO/MnO versus Mg# trend for 14 basaltic shergottites (red dots) [6]. Although the range of FeO/MnO values is fairly narrow (33-46), a linear regression (red line) indicates that FeO/MnO decreases with Mg#. This trend argues against the assumption of Dreibus and Wänke [1] that FeO/MnO of SNC meteorites is constant. The shergottite regression line does not intersect DW-Mars coordinates of FeO/MnO=38.9 and Mg#=75 (green hexagon), instead it intersects the trend of chondrites (blue diamonds and blue line) [7] at approximately the average value of H-chondrite (FeO/MnO=33.2 and Mg#=80). Thus, it could be argued that the basaltic shergottites are derived from a chondritic (with respect to major elements) Martian mantle that has a lower FeO/MnO and higher Mg# than DW-Mars.

This hypothesis is supported by our high pressure melting experiments [8] of the Homestead L5 chondrite, the silicate fraction of which is very close in composition to DW-Mars. In these experiments run at 5 GPa, garnet, low-calcium pyroxene, and olivine coexist with silicate liquids that have the super-chondritic CaO/Al_2O_3 of shergottite parent magmas, but also have much higher FeO contents. We performed some initial analyses of Mn partitioning in these experiments and determined that the Mn bulk solid/liquid partition coefficient is approximately unity. Adopting $D_{Mn}=1$ we calculated FeO/MnO for the 5 GPa experimental liquids and they are given in figure 1 as black dots with a black line showing their linear regression. The trend of the Homestead experimental liquids have much higher values of FeO/MnO than the basaltic shergottite trend and the calculated shergottite parent magma "Eg" (red squares) [9, 10]. The regression line of the experimental liquids projects back to the chondritic trend very close to average L-chondrite, recovering the Homestead starting composition, thus indicating mass balance and experimental equilibrium.

The large mismatch between the basaltic shergottite trend and the 5 GPa experimental liquid trend in figure 1 suggests that Homestead, average L-chondrite, and similar compositions such as DW-Mars are not good candidates for shergottite parent magma source regions in the Martian mantle. This conclusion is supported by recent forward modeling [11] of Martian magma ocean crystallization that produces shergottite sources with compositions similar to the silicate fraction of H-chondrite. These models, which are independent of the experimental observations considered here, appear to satisfy most constraints of shergottite major, trace, and isotopic compositions. Currently we are testing our prediction that the major-element compositions of shergottite source regions are better approximated by the silicate fraction of average H-chondrite. Accordingly we will present new high pressure melting data on the Farmville H4 chondrite.

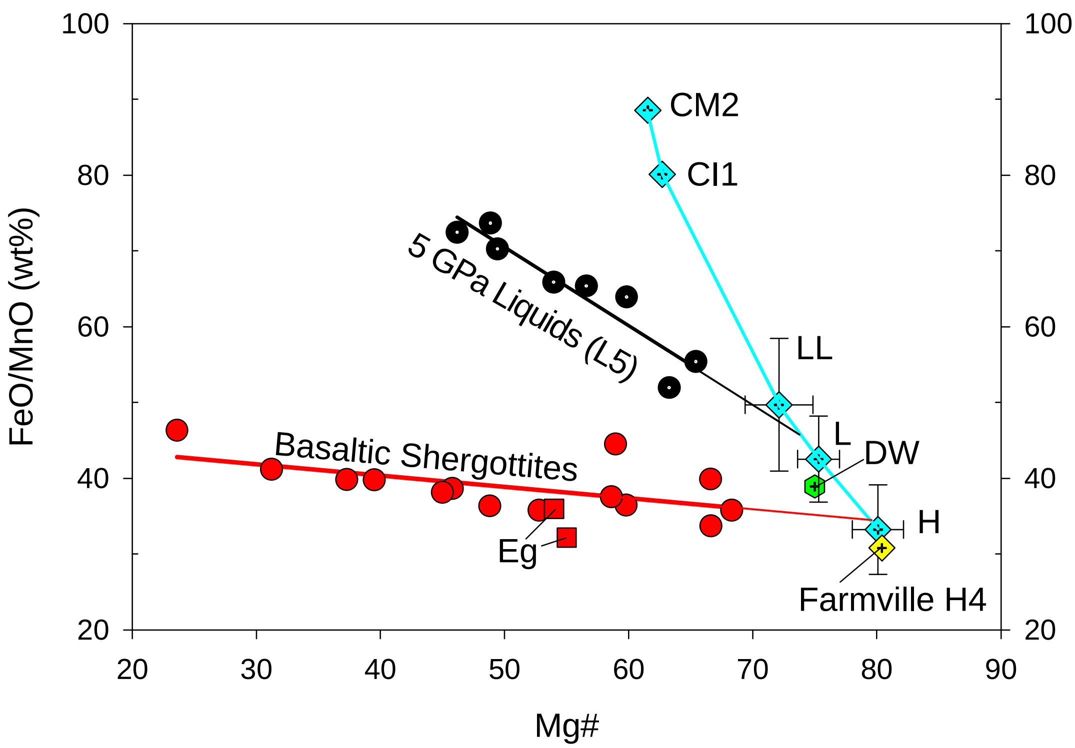

Figure 1. FeO-MnO-Mg# values for basaltic shergottites, shergottite parent magma (Eg), partial melts of Homestead (L5) at 5 GPa, average chondrites with sd-error bars, Farmville (H4), and DW-Mars.

Conclusions: Constraints from geophysics, mineral physics, high-pressure experimental petrology, and the increasing geochemical database of new Martian meteorites suggest that the bulk Fe and mantle FeO-content of DW-Mars is too high. Our high pressure data argue for an H-chondrite-like shergottite parent source region. Because the current sampling of Mars is quite limited and because we have no mantle xenolith samples or seismological measurements it is unclear whether the shergottite parent source region is equivalent to the bulk Martian mantle or whether it is a distinct region within a chemically heterogeneous mantle structure.

References:

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